

# Effects of Special Use Airspace On Economic Benefits Of Direct Flights

Koushik Datta and Craig Barrington

## Abstract

A methodology for estimating the economic effects of Special Use Airspace (SUA) on direct route flights is presented in this paper. The methodology is based on evaluating operating costs of aircraft and analyzing the different ground-track distances traveled by flights under different air traffic scenarios. Using this methodology the following objectives are evaluated: optimistic bias of studies that assume accessible SUAs, the maximum economic benefit of dynamic use of SUAs, and the marginal economic benefit of the dynamic use of individual SUAs.

## Background

In the current Air Traffic Control (ATC) system, a system of preferred routes has been established to guide pilots flying under Instrument Flight Rules (IFR) in planning their flight route and “to aid in the efficient, orderly management of the air traffic using federal airways” (NOAA, 1996). These ATC preferred IFR routes are designed to serve the needs of airspace users and provide for systematic flow of air traffic in the major terminal and en route flight environments. “Cooperation by all pilots in filing preferred routes will result in fewer traffic delays and will better provide for efficient departure, en route and arrival air traffic service” (NOAA, 1996). This system of ATC preferred IFR routes exists only between certain city pairs.

Previous studies have examined the effects of moving from the current ATC system, which includes a preferred route structure, to a system without preferred routes. Ball et al. (1995) examined moving to a system which combines wind-optimized routes for flight distances

greater than 500 nm and direct routes for flight distances less than 500 nm. Couluris and Dorsky (1995) investigated the potential benefits of moving from ATC preferred routes to user-optimized routes. Datta and Schultz (1995) examined differences between current ATC preferred route flights and direct route flights. One simplification common to these studies was the neglect of effects of Special Use Airspace (SUA) on flight paths, i.e. simulated flights were not required to avoid SUA. This simplification results in some exaggeration of the benefits of moving from the current ATC system.

The above mentioned studies were motivated by the need to establish the benefits of a less restrictive air traffic management scenario called “Free Flight”. Direct-route flight is one type of free flight where aircraft follow the shortest ground-track route from origin to destination. Whereas ATC preferred routes steer around certain types of SUAs, direct routes may conflict with one or more inaccessible SUA. In cases where the direct route passes through SUAs, if access to these SUAs is not available, the shortest path must avoid the SUAs and is, therefore, longer than the direct route. It should be noted, though, that for most origin-destination airport pairs in use, there are no intervening SUAs on the direct route.

### Special Use Airspace

“Special use airspace consists of airspace of defined dimensions identified by an area on the surface of the earth wherein activities must be confined because of their nature, or wherein limitations are imposed upon aircraft operations that are not a part of those activities, or both” (TAB, 1996). SUAs are of the following types - Alert Areas, Controlled Firing Areas, Military Operations Areas, National Security Areas, Prohibited Areas, Restricted Areas and Warning Areas. In this study, only Prohibited and Restricted Areas are considered. The others are non-

regulatory special use airspace and we assume unrestricted access to them. From this point onward, references in this paper to SUAs are to a combination of Prohibited and Restricted Areas. Commercial aircraft flight is never allowed through Prohibited Areas, whereas it is sometimes possible for commercial aircraft to traverse some restricted areas. This is because many Restricted Areas are designated as “joint use” and commercial flight operations in the SUA may be authorized by the controlling ATC facility when the SUA is inactive.

### Dynamic Use of SUAs

Special use airspace is an important factor affecting free flight. The concept of accessing SUAs during periods of inactivity suggests the opportunity for economic benefits to all other airspace users. Increased public access during periods of SUA inactivity is termed “dynamic use of SUA”, and has been identified by the RTCA Task Force 3 (1995) as a concept on the evolutionary course to free flight. Previous studies (Ball et al., 1995; Couluris et al., 1995; Datta et al., 1995), which ignored effects of SUAs on direct routes were, in effect, estimating the upper bound on the economic benefits of Free Flight.

The thrust of this study is to examine the maximal effect of dynamic use of SUAs, i.e. complete access to SUAs, on the economic benefits of minimum-distance routes. Direct, or great circle, route flights are compared to shortest route flights avoiding SUAs.

### **Objectives**

The objectives of this study are to evaluate order-of-magnitude estimates of:

- 1) the optimistic bias of previous economic analyses which compared ATC preferred route flights to direct route flights that assumed unrestricted access to SUAs. This analysis focuses only on air traffic on the ATC preferred routes.

- 2) the maximum possible economic benefit of dynamic use of SUAs compared to minimum-distance routes that avoid SUAs. All traffic is considered in this analysis.
- 3) the marginal economic benefit of the dynamic use of individual SUAs. And, to identify those SUAs having the greatest potential benefits. All traffic is considered in this analysis.

This study considers only economic effects of SUAs on flight path length. Potential conflicts and delays caused by other effects of SUAs, such as air traffic congestion, are not addressed in this study. For a complete evaluation of the effect of SUAs on air traffic flow safety and economics, all of these effects should be considered together.

This study applies only to scheduled, Instrument Flight Rules (IFR) flights. No Visual Flight Rules (VFR) traffic data was available.

### **Mathematical Formulation**

The indices  $i$ ,  $j$  and  $k$ , as subscripts, denote aircraft type, origin-destination airport pair, and individual SUAs, respectively. Subscripts  $p$ ,  $s$  and  $d$  denote ATC preferred route flights, shortest route flights avoiding SUAs and direct route flights, respectively. The rest of the notation is:

$c_i$  = Operating cost rate of aircraft type  $i$  (\$/nm/aircraft),

$j \in J$  = Set of all airport pairs in the traffic schedule,

$j \in J_p$  = Set of airport pairs corresponding to all ATC preferred routes that have at least one flight in the traffic schedule,

$L_0$  = Set of all SUAs,

$L_k$  = Set of all SUAs except for the  $k^{\text{th}}$  SUA,

$p_j$  = Distance of the ATC preferred route for airport pair  $j$  (nm),

$d_j$  = Direct route distance of airport pair  $j$  (nm),

$s_{jk}$  = Shortest route distance avoiding the  $L_k$  set of SUAs between airport pair  $j$  (nm),

$n_{ij}$  = Number of aircraft of type  $i$  in the traffic schedule that fly between airport pair  $j$   
(aircraft/day),

The cost multiplier (\$/nm/day) for the  $j^{\text{th}}$  airport pair is given by:

$$m_j = \sum_i n_{ij} \times c_i \quad (1)$$

The annual cost (\$/yr) of aircraft flying on ATC preferred routes for the set of airport pairs  $J_p$ , i.e. those airport pairs having preferred routes between them, is:

$$C_p(J_p) = 365 \times \sum_{j \in J_p} m_j \times p_j \quad (2)$$

The annual cost (\$/yr) of aircraft flying on direct routes for the set of airport pairs  $J_p$  is:

$$C_d(J_p) = 365 \times \sum_{j \in J_p} m_j \times d_j \quad (3)$$

The annual cost (\$/yr) of aircraft flying on shortest routes for the set of airport pairs  $J_p$  and avoiding all the SUAs ( $L_0$  set) is:

$$C_s(J_p, 0) = 365 \times \sum_{j \in J_p} m_j \times s_{j0} \quad (4)$$

The annual cost (\$/yr) of aircraft flying on direct routes for the set of airport pairs  $J$ , i.e. all city pairs, is:

$$C_d(J) = 365 \times \sum_{j \in J} m_j \times d_j \quad (5)$$

The annual cost (\$/yr) of aircraft flying on shortest routes for the set of airport pairs  $J$  and avoiding the  $L_k$  set of SUAs, i.e. all SUAs except for the  $k^{\text{th}}$  SUA, is:

$$C_s(J, k) = 365 \times \sum_{j \in J} m_j \times s_{jk} \quad (6)$$

In evaluating equations (4) and (6) the SUAs are assumed to be inaccessible at all times. A check of the SUA times-of-use data showed that 97% of them are either continuously inaccessible or can be activated by a notice to airmen within a few hours (NFDC, 1995). This assumption is judged reasonable a posteriori, as the results show that SUAs with the largest economic effect have continuous times of use.

Based on the above six equations, the three objectives are evaluated as follows:

- 1) The annual economic benefit of aircraft flying direct routes instead of ATC preferred routes ( $C_p(J_p) - C_d(J_p)$ ) is compared against the annual economic benefit of aircraft flying shortest routes avoiding SUAs instead of ATC preferred routes ( $C_p(J_p) - C_s(J_p, 0)$ ). Comparing these in percentage terms quantifies the optimistic bias of assuming access to all SUAs. Only air traffic on ATC preferred routes (set  $J_p$ ) are considered.
- 2) The annual economic benefit of all aircraft (set  $J$ ) flying direct routes instead of shortest routes avoiding SUAs ( $C_s(J, 0) - C_d(J)$ ) is an estimate of the maximum economic benefit of dynamic use of SUAs. This corresponds to a scenario where air traffic always has access to fly through SUAs at the desired times.
- 3) Rank in decreasing order the economic benefit of access to a SUA ( $C_s(J, 0) - C_s(J, k)$  for all  $k$ ), i.e., where only one SUA is available for flights through it while all other SUAs are inaccessible. This is an estimate of the marginal maximum economic benefit of the dynamic use of a SUA.

## Analysis

### Data and Software Tools Used

*IFR traffic schedule:* The IFR traffic schedule file was obtained from Seagull Technology, Inc. and represents a typical, busy day in the year 1995. This traffic schedule includes flights either into and/or out of 70 major US airports, the vast majority of all the scheduled IFR air traffic in the USA. The schedule specifies each flight's identification number, aircraft equipment type, origin and destination airport, and scheduled gate arrival and departure time.

*ATC preferred route:* ATC preferred route data, airways data, airport data, navigation aid data and fix data were obtained from the FAA's National Flight Data Center (NFDC, 1995). The ATC preferred route data consists of a combination of airport, airways, navigation aid, fixes, standard terminal arrival routes and standard instrument departure routes. Software was written to convert the ATC preferred route data into routes consisting of locations and, further, to evaluate the length of each route. Some city pairs have more than one high/low altitude ATC preferred IFR route, for example: one for over-water flight and one for over-land flight. In these cases, the shortest route was chosen as the desired preferred route. A limitation of the NFDC data base is that it does not include ATC preferred routes that are defined by a Memorandum of Understanding or other agreements.

*Shortest route avoiding SUA:* Software was written to generate the shortest ground-track path that avoids SUAs between airport pairs and to evaluate the path length. Such paths may follow the edges of SUAs. SUA boundary data was obtained from the FAA (NFDC, 1995). Only Prohibited and Restricted SUAs were used in the analysis. These SUAs are shown in Figure 1.

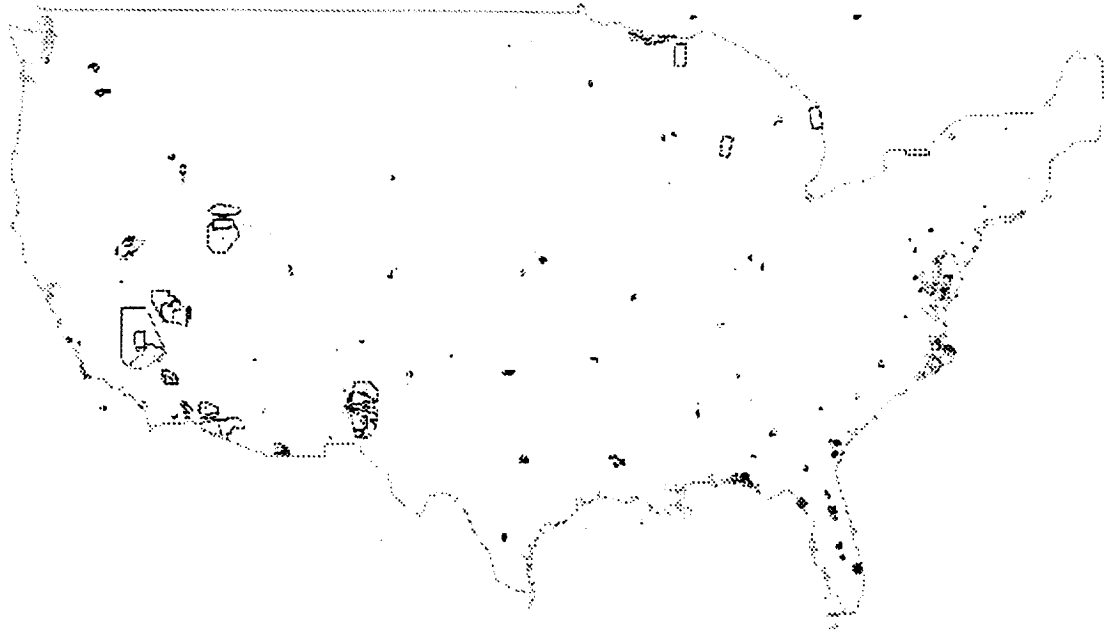


Figure 1: Prohibited and Restricted Special Use Airspace in Continental USA

*Aircraft operating cost rate:* Approximate aircraft operating cost rates (\$/nm/aircraft) were obtained by dividing the direct operating cost rates (\$/hr) by aircraft cruise speeds (nm/hr). The direct operating cost rates were obtained from Couluris and Dorsky (1995) for various aircraft classes, while aircraft cruise speeds were obtained from Abkin and Olmstead (1989) for representative aircraft in each aircraft class. This approximation underestimates costs because aircraft travel slower during the acceleration-to-cruise and deceleration-from-cruise phases of flight.

*Cruise altitude of flights:* The altitude profiles of the flights in the schedule were determined by the Total Airspace & Airport Modeller (The Preston Group, 1995), an air traffic simulation software package. The software bases its cruise altitude predictions on aircraft performance data, ATC rules, and the route characteristics.



## Evaluation

The very large number of aircraft types in the IFR traffic schedule were categorized into aircraft classes based on attributes significant to cost, as in Couluris and Dorsky (1995). The significant attributes were: the number of engines (1, 2, 3 or 4), type of engine (jet, turboprop or piston) and aircraft size (heavy, large-to-heavy, large, large-to-small or small). This categorization provides a method to correlate direct operating cost rates (\$/hr) with aircraft types. From the IFR traffic schedule data, the 102 aircraft types were categorized into 19 classes. A typical cruise speed (nm/hr) was then selected for each of these aircraft classes from data in Abkin and Olmstead (1989). An operating cost rate in \$/nm/aircraft was obtained from the ratio of these two numbers. These cost rates are listed in Table 1 below.

Aircraft classes from IFR traffic schedule (NT/A)	Operating cost rate (\$/nm/aircraft)	Aircraft classes from IFR traffic schedule (NT/A)	Operating cost rate (\$/nm/aircraft)
4J/H	8.08	4T/L	3.86
4J/L	3.81	2T/L	1.55
3J/H	6.20	2T/S	1.43
3J/L	3.29	1T/S	1.63
2J/H	4.59	4P/L	4.33
2J/LH	3.24	2P/L	3.45
2J/L	2.56	2P/S	1.58
2J/LS	2.36	1-2P/S	1.32
2J/S	1.72	1P/S	0.75
		SST	5.94

Format of aircraft classes is NT/A, where N is number of engines, T is type of engine and A is aircraft size.

Number of engines: 1, 2, 3 or 4

Type of engine: Jet (J), Turboprop (T) or Piston (P)

Aircraft size: Small (S), Large-to-small (LS), Large (L), Large-to-heavy (LH) or Heavy (H)

Table 1: Aircraft classes and their operating cost rates (in 1995 \$/nm/aircraft)

The operating cost rates of Table 1 represent costs directly related to time spent in actual flight. They include crew, maintenance and airborne fuel cost rates and do not include passenger

costs. These cost rates are in 1995 dollars per nautical mile and correspond to  $c_i$  in the mathematical formulation.

From an original database describing all SUAs in the USA, two sets of SUA boundary data were built. The first set includes those SUAs which obstruct high altitude flights (18,000 feet and above). The second set includes those SUAs which obstruct low altitude flights (less than 18,000 feet). The two sets overlap significantly. This grouping was chosen, in part, due to the two types of enroute charts available. Although grouping SUAs into two types simplifies the problem, it does not provide an accurate representation for all SUAs. Some Restricted Areas may not affect certain flights, depending on the altitudes of the SUAs and the flights. One example, of an extreme case, is the Restricted Area 2903-D in Florida that only goes up to 5,000 feet but is categorized in our methodology as affecting low altitude flights. However, most of the SUAs generally do affect the flights as categorized above.

Using the IFR traffic schedule and the cruise altitudes of these flights, the choice of high or low altitude route is decided on a case-by-case basis. It is assumed that if they fly high altitude routes, they are only affected by high altitude SUAs, whereas if they fly low altitude routes, they are only affected by low altitude SUAs.

For each route (from origin to destination, high or low) the number of aircraft belonging to each class ( $n_{ij}$ ) are then counted. Then, the cost multiplier,  $m_j$  (\$/nm), is evaluated as per equation (1) for each route ( $j$ ) based on number of aircraft in each class that fly the route per day and the operating cost rate,  $c_i$  (\$/nm/aircraft), for each class. The cost multiplier multiplied by the distance of the route represents the total daily operating cost of flights on that route.

To quantify the optimistic bias of previous studies that assume access to SUAs for direct route flights, only flights that qualify for a high or low altitude ATC preferred route are considered (set  $J_p$ ). Tower enroute control flights were not considered because these are flights of shorter length (median length of about 150 nm) and the methodology of this study (based on \$/nm/aircraft derived from cruise speeds) was thought to be less applicable under these conditions.

For origin-destination airport pairs corresponding to the high and low altitude ATC preferred routes, flight distances are evaluated on the shortest ATC preferred route ( $p_j$ ), shortest route avoiding SUAs ( $s_{jo}$ ), and the direct route ( $d_j$ ). The direct route distance corresponds to the great circle distance between the airport pairs. The ATC preferred route is longer than or equal to the shortest route avoiding SUAs, which is longer than or equal to the direct route. Figure 2 presents the curves for two ratios of these distances. The upper curve is the ratio of the shortest route distance avoiding SUAs to the direct route distance. As seen from the intercept of this curve, in only about one third of the cases it was actually larger, indicating that in these cases the direct route passed through a SUA. The lower curve is the ratio of the ATC preferred route distance to the direct route distance. Very few of the route distance ratios are 1.0 indicating that almost all ATC preferred routes are longer than direct routes. The ATC preferred route distance was also larger than the length of the shortest route avoiding SUAs, as seen from the difference between the two curves. These curves provide a preview to the economic benefit results - there is a larger savings available in moving from ATC preferred routes to direct routes than in moving from shortest routes avoiding SUAs to direct routes.

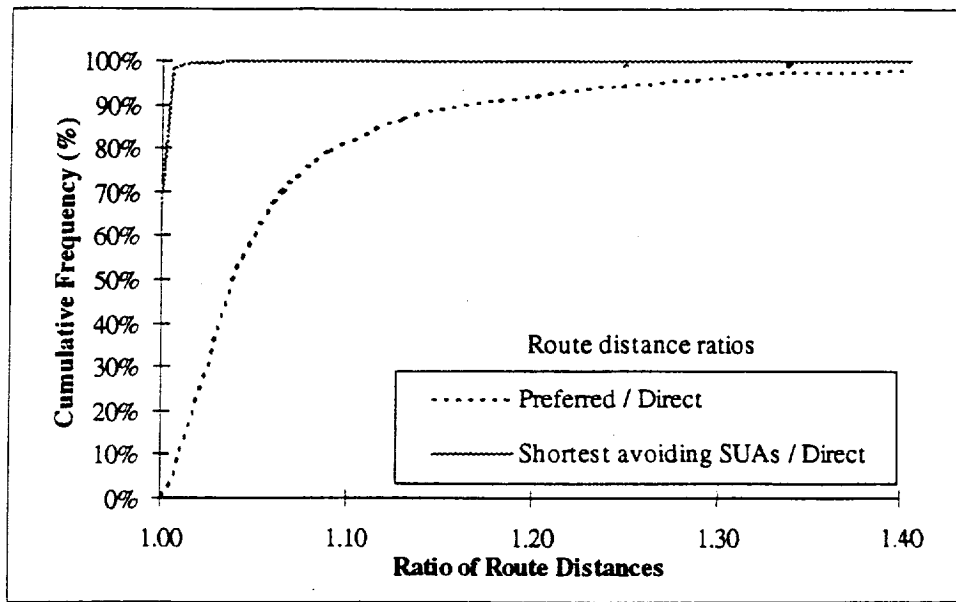


Figure 2: Comparison of route distance ratios for city pairs that have ATC preferred routes

For the analysis of maximum economic benefit of dynamic use of SUAs, all IFR flights in the data base are taken into consideration (set J). For origin-destination airport pairs corresponding to these flights, distances are evaluated on the shortest route avoiding all SUAs ( $s_{j0}$ ) and the direct route ( $d_j$ ). Again, the length of the shortest route avoiding SUAs must be greater than or equal to the direct route distance.

For the analysis of marginal economic benefit of dynamic use of SUA groups, only routes where the shortest distance avoiding SUAs is larger than the great circle distance were considered. For simplicity, all contiguous SUAs were grouped together and the marginal economic benefit of the group of contiguous SUAs was calculated. One SUA group (group k) was then removed from the set of all SUAs (to form set  $L_k$ ). For all the routes under consideration, the shortest route distance ( $s_{jk}$ ) avoiding the rest of the SUAs was evaluated. This process is repeated for each SUA group in turn.

Equations (1) through (6) were evaluated and the desired results are presented in the next section and in tables 2, 3 and 4.

## Results

All economic benefit results are presented in 1995 dollars. As explained previously, the aircraft operating cost rates are biased low (conservative), so the total evaluated costs are also biased low. However, ratios of costs are assumed to be more realistic because the bias is assumed to affect both the numerator and the denominator of the ratios similarly.

### Economic Benefit of Different Air Traffic Flight Scenarios

The results of the comparisons of economic benefits for different flight scenarios are summarized in Table 2 below. Only 7,566 of the 33,271 IFR flights/day in the schedule had corresponding ATC preferred routes. These 7,566 flights were first assumed to fly on ATC preferred routes, then on shortest routes avoiding all SUAs and finally on direct routes. The difference in distances flown between ATC preferred routes and direct routes for all 7,566 flights was 220,000 nm per day. This corresponds to a potential, daily operating cost savings of \$693,000 and a potential annual operating cost savings of \$253 million. In a previous study (Couluris and Dorsky, 1995), the savings from user-optimized routes with access through SUAs

	ATC preferred routes to Direct routes	ATC preferred routes to Shortest routes avoiding SUAs	Shortest routes avoiding SUAs to Direct route
Daily flight distance savings (1000 nm)	220	218	2.6
Daily operating cost savings (\$ thousands)	693	685	8
Annual operating cost savings (\$ million)	253	250	3
Percentage of operating cost savings	100%	98.8%	1.2%

Total number of flights per day = 7,566

Total number of routes = 1,075

Table 2: Comparisons of economic benefits (in 1995 \$) for different flight scenarios

was estimated to be \$332 million/year. Comparison of these two results show that this study's estimate of the savings is lower than that of Couluris and Dorsky (1995). However, Couluris and Dorsky (1995) assumed user preferred routing (as compared to direct routing) taking into account prevailing winds. The other difference is that this study's estimate has a conservative bias because of the use of cruise speeds in estimating the operating cost rate (\$/nm) and the use of a limited IFR traffic schedule.

When ATC preferred route flights are compared to shortest routes avoiding SUAs, the total of differences in the distances flown is 218,000 nm, corresponding to a daily and annual operating cost savings of \$685,000 and \$250 million, respectively. The last column of Table 2 compares the shortest routes avoiding SUAs to direct routes. These results are the difference between the previous two columns of results in Table 2.

If the savings in going from ATC preferred routes to direct routes is assumed to be the maximum savings of a 100%, then when SUAs are taken into account and shortest routes avoiding SUAs are used instead of direct routes the available savings is 98.8%. This result shows that the estimates made with no consideration to SUAs in other studies are of the correct order-of-magnitude. This result quantifies objective 1 of this paper: the optimistic bias of previous economic analyses which assumed access through SUAs is only 1.2%.

#### Maximum Economic Benefit of Dynamic Use of all SUAs

The results of the analysis of maximum economic benefit of dynamic use of SUAs are summarized in Table 3 below. When all 33,271 IFR flights/day on 6,818 routes in the schedule were flown on shortest routes avoiding SUAs, only 16% of the flights and only 18% of the routes were affected by SUAs. For flights on these routes, the total of the differences in distances flown

between shortest routes avoiding SUAs and direct routes was 7,000 nm. This corresponds to a potential daily and annual operating cost savings of \$21,000 and \$7.8 million, respectively.

This result quantifies objective 2 of this paper: the maximum economic benefit of dynamic use of SUAs is about \$7.8 million annually. From the IFR schedule, the route with the maximum savings benefit (\$ 520,000 annually) is the Phoenix, AZ to San Francisco, CA route, while the route with the maximum distance savings (25 nm) is the Las Vegas, NV to San Luis Obispo, CA route.

	Percentage of IFR flights	Percentage of routes with IFR flights	Daily flight distance difference (1000 nm)	Daily operating cost difference (\$ thousands)	Annual operating cost difference (\$ millions)
Affected by SUAs	16	18	7	21	7.8
Total number of flights per day = 33,271			Total number of routes = 6,818		

Table 3: Economic benefit of dynamic use of SUAs (in 1995 \$)

#### Marginal Economic Benefit of Dynamic Use of One SUA

The results of the analysis of the marginal economic benefit of dynamic use of SUA groups are summarized in Table 4 below. The SUA groups are ranked in decreasing order of marginal economic benefit. The top ten are high altitude SUA groups, while the top low altitude SUA group, near Eglin Air Force Base, Florida, is ranked 19th. These SUA groups and their locations are shown in Figure 3 - most of these SUAs are located in the western part of the USA. These western SUAs are also the larger SUAs in the country. However, the marginal economic benefit of the SUAs is not solely dependent on size, as seen from Figure 3, where some smaller SUA groups that affect more flights are ranked higher than others with larger areas. The largest economic benefit of dynamic use of a SUA group is \$ 7600 daily or \$ 2.8 million annually for the

group of SUAs over Edwards Air Force Base and Naval Air Weapons Station, China Lake, California. The marginal benefits decrease quite rapidly as the tenth-ranked SUA group has marginal economic benefits of only \$ 0.1 million annually, 4% of the marginal economic benefit of the first group.

Ranking	SUA Group		Savings in operating costs	
	Names	High/Low	Daily (\$ thousands)	Annual (\$ millions)
1	R-2502E&N, R-2505, R-2508, R-2515, R-2524 over Edwards AFB and NAWS China Lake, CA	High	7.6	2.8
2	R-5103C&D, R-5107A to G, R-5109A&B, R-5111A&C over White Sands Missile Range, NM	High	4.7	1.7
3	R-4806E&W, R-4807A&B, R-4808N&S, R-4809 North-west of Nellis AFB, NV	High	2.6	1.0
4	R-6402A&B, R-6405, R-6406A&B, R-6407 Near Wendover, UT	High	1.7	0.6
5	R-2501N,E,W&S over Twentynine Palms, CA	High	1.3	0.5
6	R-2306A,B,D&E, R-2307, R-2308A,B&C Yuma Proving Ground, AZ	High	0.7	0.3
7	R-4002, R-4005, R-4006, R-4008, R-6609 Near NAS Patuxent River, MD	High	0.6	0.2
8	R-2507N&S over Chocolate Mountains, CA	High	0.4	0.2
9	R-2301E&W, R-2304, R-2305 Near Gila Bend, AZ	High	0.4	0.1
10	R-4001A&B Aberdeen Proving Ground, MD	High	0.3	0.1
19	R-2914A&B, R-2917, R-2918, R-2919A&B near Eglin AFB, FL	Low	0.08	0.03

All the above mentioned SUA groups consist of Restricted Areas (indicated by a prefix R-).  
All contiguous SUAs were grouped together by the authors for this analysis.

Table 4: Marginal economic benefit (in 1995 \$) rankings for dynamic use of SUA groups



This result quantifies objective 3 of the paper: the marginal maximum economic benefit of dynamic use of one SUA group is about \$2.8 million annually.

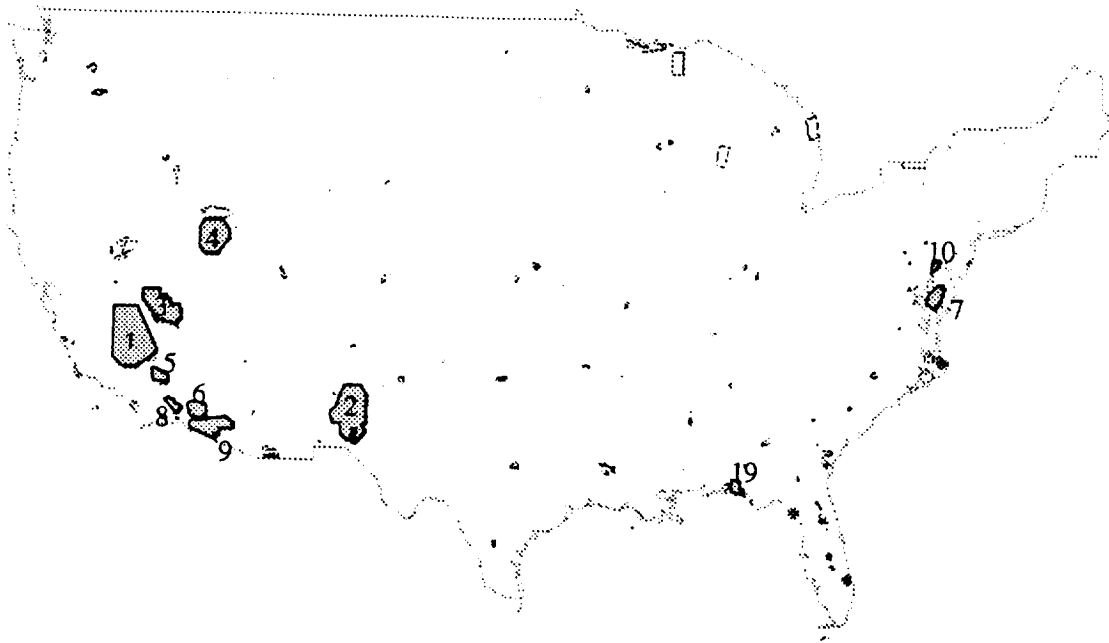


Figure 3: Groups of SUAs with the largest marginal economic benefit for dynamic use

## Conclusions

A methodology was presented for estimating the economic effects of Special Use Airspace on direct route flights. The results (in 1995 \$) for restricted and prohibited areas are summarized below.

- 1) The optimistic bias of economic analyses which compared ATC preferred route flights to direct route flights that ignore the effects of SUAs is only 1.2%. Therefore, when access to fly through SUAs is not available, 98.8% of the economic benefits of direct route flights are still realizable.

- 2) The maximum economic benefit of dynamic use of all SUAs is about \$7.8 million annually. This result is based on the scenario where air traffic operating on direct routes that pass through a SUA have access to fly through that SUA at the desired time.
- 3) The results show that the top ten SUA groups, those with the largest marginal economic benefits of the dynamic use of those SUAs, all affect high altitude flights and are typically located in the western part of the country. The marginal maximum economic benefit of dynamic use of a SUA group is \$2.8 million annually. The SUA group that has the tenth largest marginal economic benefit corresponds to a savings of only \$0.1 million annually. The marginal maximum economic benefit of dynamic use of a SUA corresponds to a scenario where only that SUA is available for flights through it, while all others are unavailable.

Many effects of SUAs, such as safety of flight and congestion of traffic, and their consequences in terms of potential conflicts and delays, are not addressed in this study. For a complete evaluation of the effect of SUAs all other effects should also be considered along with the economic benefits.

Current VFR traffic data was not available and is not a part of the analysis. The IFR traffic schedule which was available and used in the analysis was limited to scheduled flights that either arrived at, or departed from, one of 70 major US airports. When all VFR and IFR traffic is considered, the results of objectives 2 and 3 could change significantly.

This study does not evaluate the effects of SUA on wind-optimized routes. However, for order-of-magnitude results, the trends in this study are thought to be representative.

## Acknowledgments

This work has been sponsored by NASA Ames Research Center under contract number NAS2-13767. The authors would like to thank Mr. David Schleicher of NASA Ames for his encouragement concerning this work. The authors would also like to thank Mr. Russ Paielli of NASA Ames and Mr. Win den Braven of Sterling Software for their comments on this paper.

## References

1. Abkin, M.H., and Olmstead, J.R. (1989), *En Route GPS Benefits Analysis Model: Technical Documentation*, Report to Systems Control Technology, Inc. from ATAC, Mountain View, CA 94042, January 1989.
2. Ball, M., DeArmon, J.S., and Pyburn, J.O. (1995), *Is Free Flight Feasible? Results from Initial Simulations*, Journal of ATC, Official Publication of the Air Traffic Control Association, Inc., January-March 1995, pages 14-17.
3. Couluris, G.J., and Dorsky, S. (1995), *Advanced Air Transportation Technologies (AATT) Potential Benefits Analysis*, Report to NASA Ames from Seagull Technology, Inc., Cupertino, CA 95014, September 1995.
4. Datta, K., and Schultz, G. (1995), *An Evaluation of TAAM for Free Flight Modeling*, Draft Report to NASA Ames from Sverdrup Technology, Inc., NASA Ames, Moffett Field, CA 94035, November 1995.
5. NFDC (1995), *Airport, Navigation Aid, Fix, Airways, and Preferred IFR Route Listings*, computer data files, National Flight Data Center, Federal Aviation Administration, Washington DC 20591, June 1995.
6. NOAA (1996), *United States Government Flight Information Publication, Airport/Facility Directory*, National Oceanic and Atmospheric Administration, Department of Commerce, Silver Spring, MD 20910, 29 February 1996.
7. RTCA (1995), *Final Report of the RTCA Task Force 3 Free Flight Implementation*, RTCA, Inc., Washington, DC 20036, October 26, 1995.

8. TAB (1996), *AIM/FAR 1996 Aeronautical Information Manual / Federal Aviation Regulations*, TAB AERO, Blue Ridge Summit, PA 17294.
9. The Preston Group (1995), *TAAM, Total Airspace & Airport Modeller, Release 2.9*, The Preston Group Pty Ltd., Richmond, Victoria 3121, Australia, 1995.

### **Indexing Terms**

Economic Benefits, Special Use Airspace, Dynamic Use of SUA, Direct Route, ATC Preferred IFR Route, Avoiding SUA.